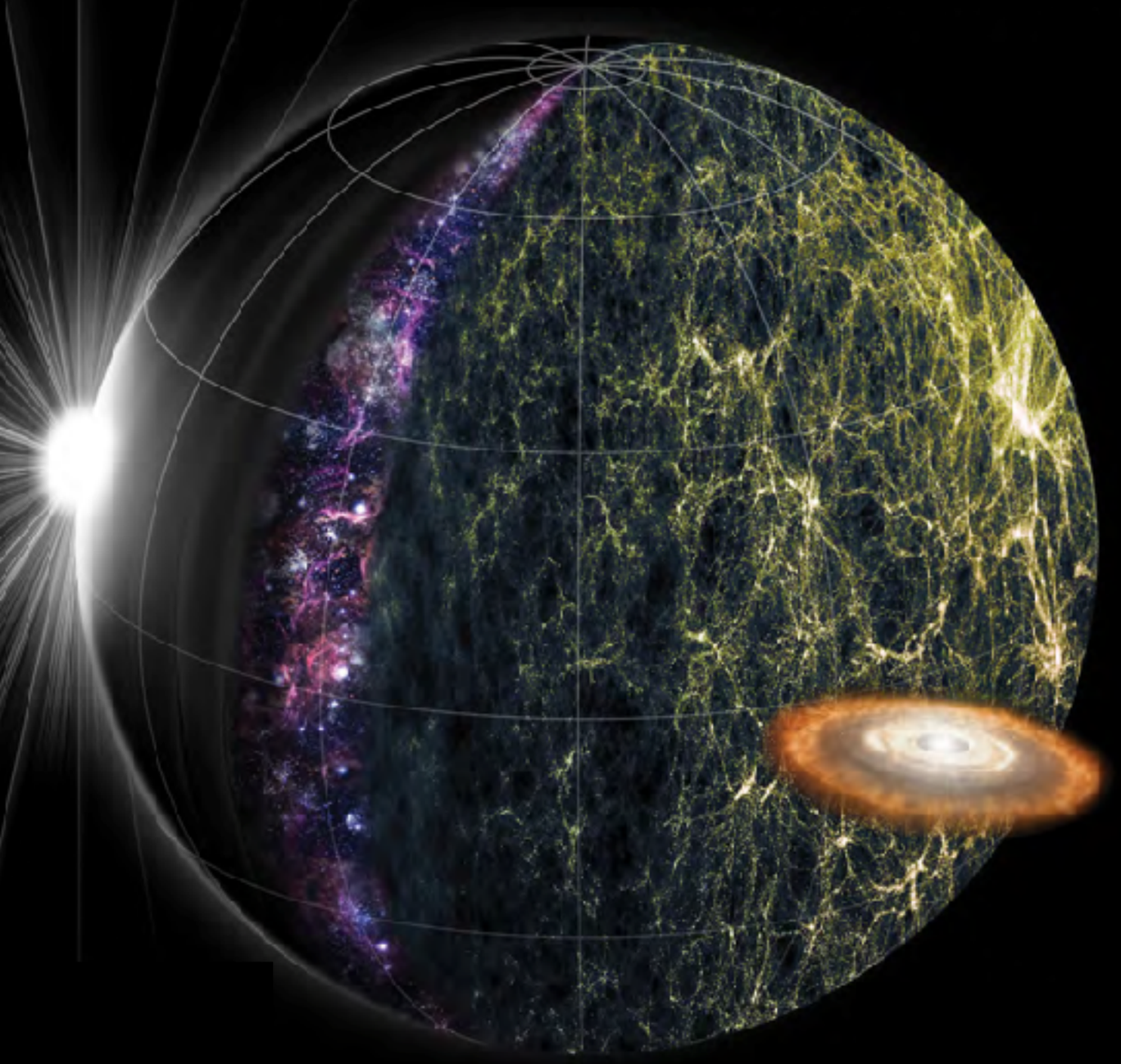
STUDYING INFLATION WITH LARGE SCALE STRUCTURES:

LIFE ON THE NON-GAUSSIANITY FRONTIER



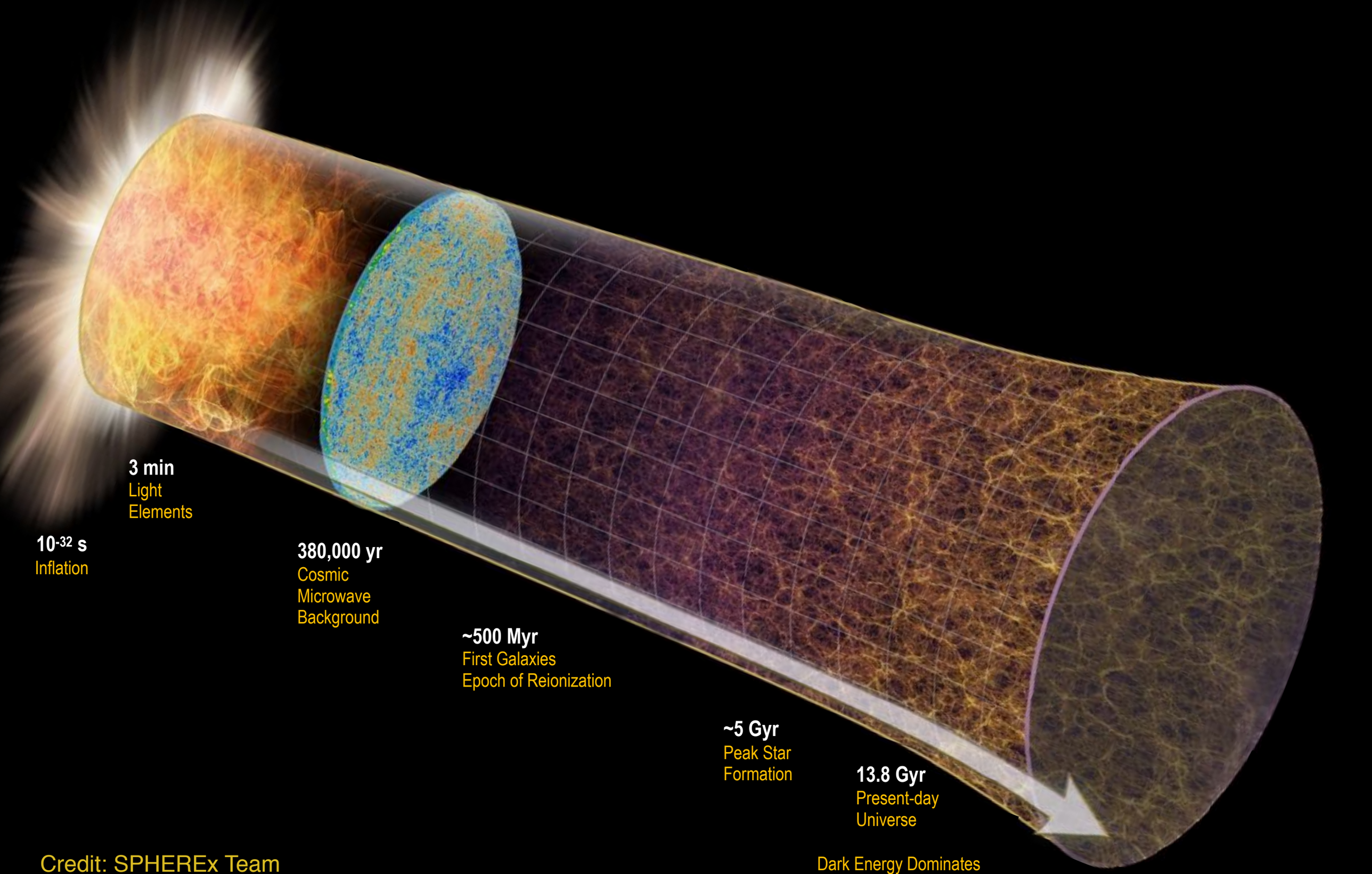
Olivier Doré
JPL/Caltech

with

Roland de Putter (*Caltech*),
Jérôme Gleyzes (*JPL/Caltech*),
Daniel Green (*UCB*),
the SPHEREx Team,
the Planck Collaboration

arXiv:1612.05248, 1612.0366, 1610.00785, 1504.05935

THE (REALLY, REALLY) BIG PICTURE



Credit: SPHEREx Team

DRIVING QUESTIONS

- What observations define our current cosmological understanding?
- What is Inflation? How to make progress in our understanding of Inflation?
- What is primordial non-Gaussianity? Why measuring primordial primordial non-Gaussianity with large scale structures?
- How well do we need to measure primordial non-Gaussianity? What can a measurement with $\sigma(f_{NL})\sim1$ tell us about multi-field inflation?
- What survey does it take to make measure $\sigma(f_{NL})\sim1$?
- A possible implementation, the SPHEREx mission

SPHEREx (-M)

An All-Sky Spectral Survey

DESIGNED TO EXPLORE:
THE ORIGIN OF THE UNIVERSE
THE ORIGIN AND HISTORY OF GALAXIES
THE ORIGIN OF WATER IN PLANETARY SYSTEMS

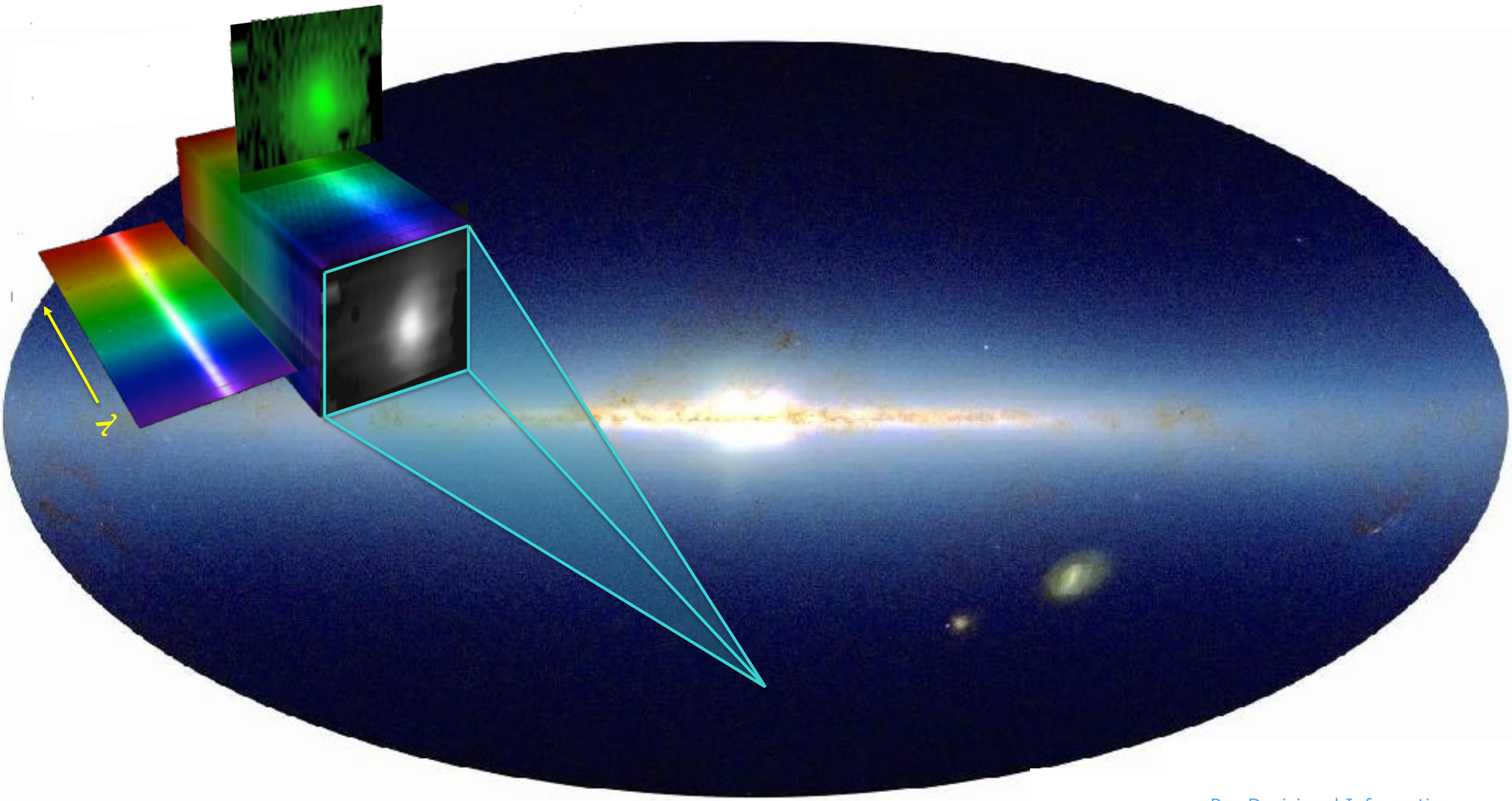
http://spherex.caltech.edu

Caltech | JPL Jet Propulsion Laboratory California Institute of Technology | Ball | ipac | CfA | UCI | The Ohio State University

SPHEREx: An All-Sky Spectral Survey

Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer

A high throughput, low-resolution near-infrared spectrometer.



Credit IPAC/2MASS

SPHEREX: AN ALL-SKY SPECTRAL SURVEY

Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer

A high throughput, low-resolution near-infrared spectrometer.

SPHEREx Dataset:

For every 6.2” pixel over the entire sky:

- ➡ R=40 spectra spanning (0.75 μm < λ < 4.18 μm).
- ➡ R=150 spectra (4.18 μm < λ < 5.0 μm).

O.D., Bock et al., arXiv:1412.4872

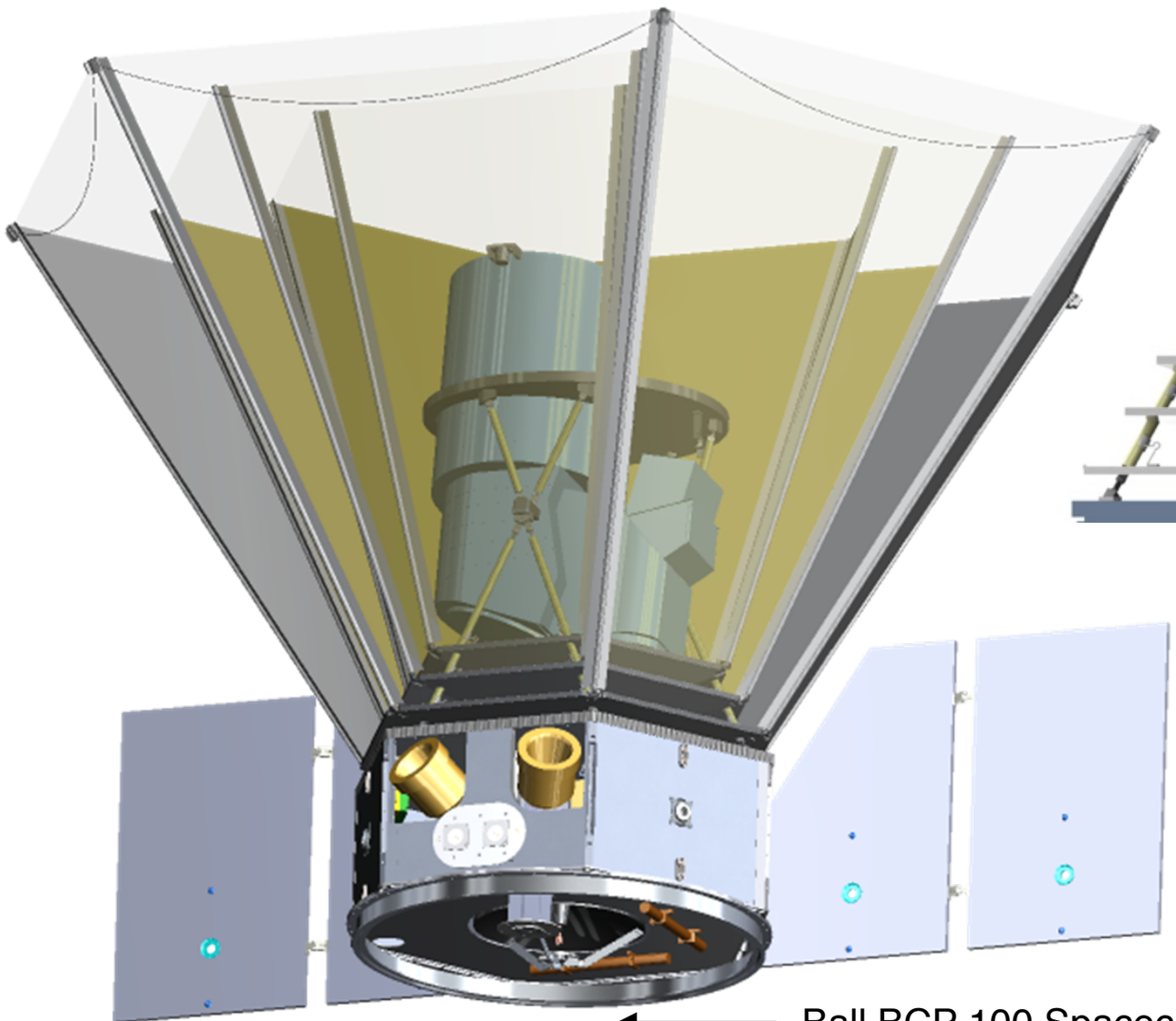
SPHEREX BASELINE DESIGN

AN INNOVATIVE ARCHITECTURE BASED ON MATURE TECHNOLOGIES

Parameter	Value
Telescope eff. diameter	20 cm
Field of view	3.5 x 7 degree
Pixel size	6.2 arcsec
Wavelength range	0.75 – 5 μm
Resolving power λ/Δλ	41 - 135

Wide field telescope

Compact spectrometer



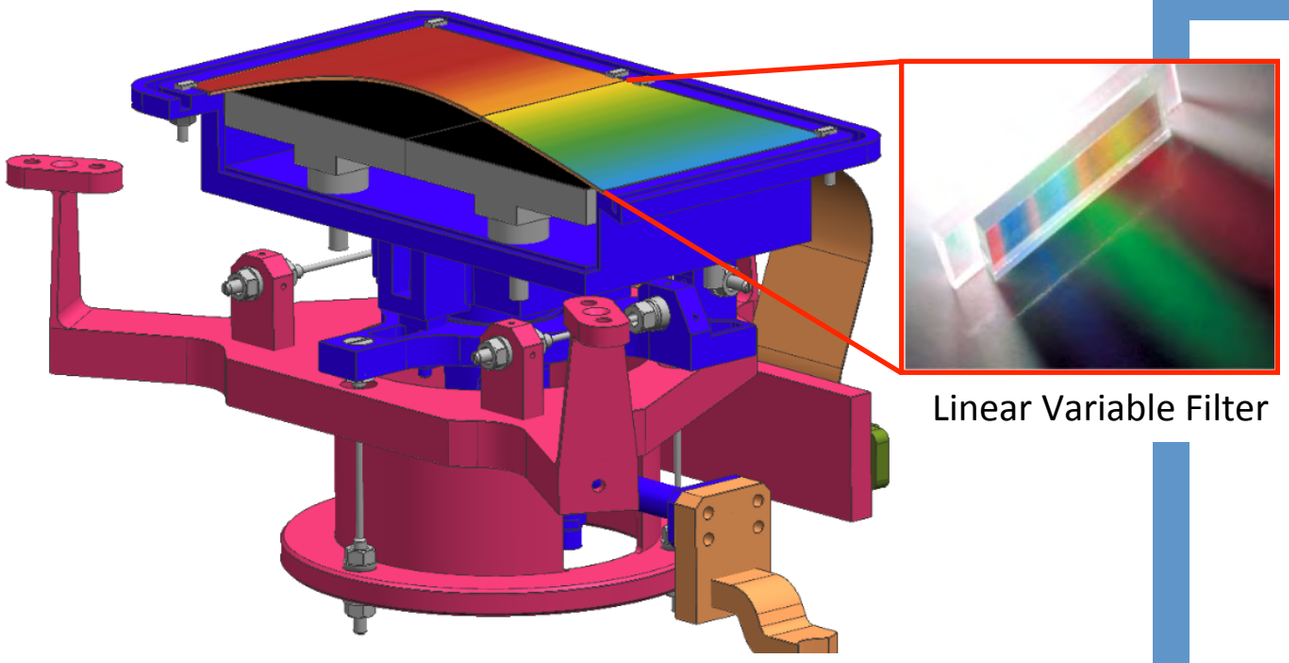
185 cm

Ball BCP 100 Spacecraft Bus

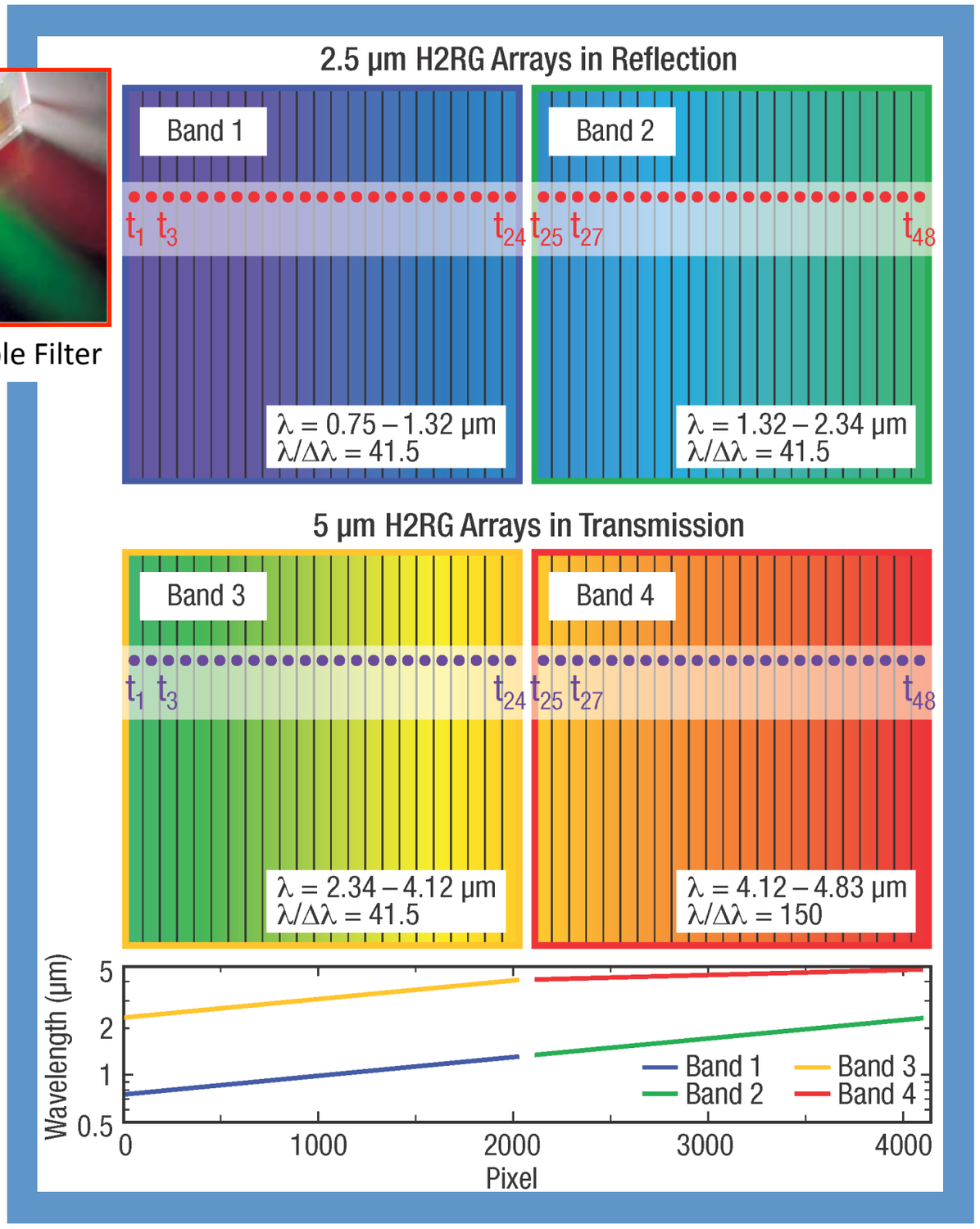
Passive cooling system

Parameter	Value
Telescope eff. diameter	20 cm
Field of view	3.5 x 7 degree
Pixel size	6.2 arcsec
Wavelength range	0.75 – 5 μm
Resolving power λ/Δλ	41 - 135

HIGH-THROUGHPUT LVF SPECTROMETER

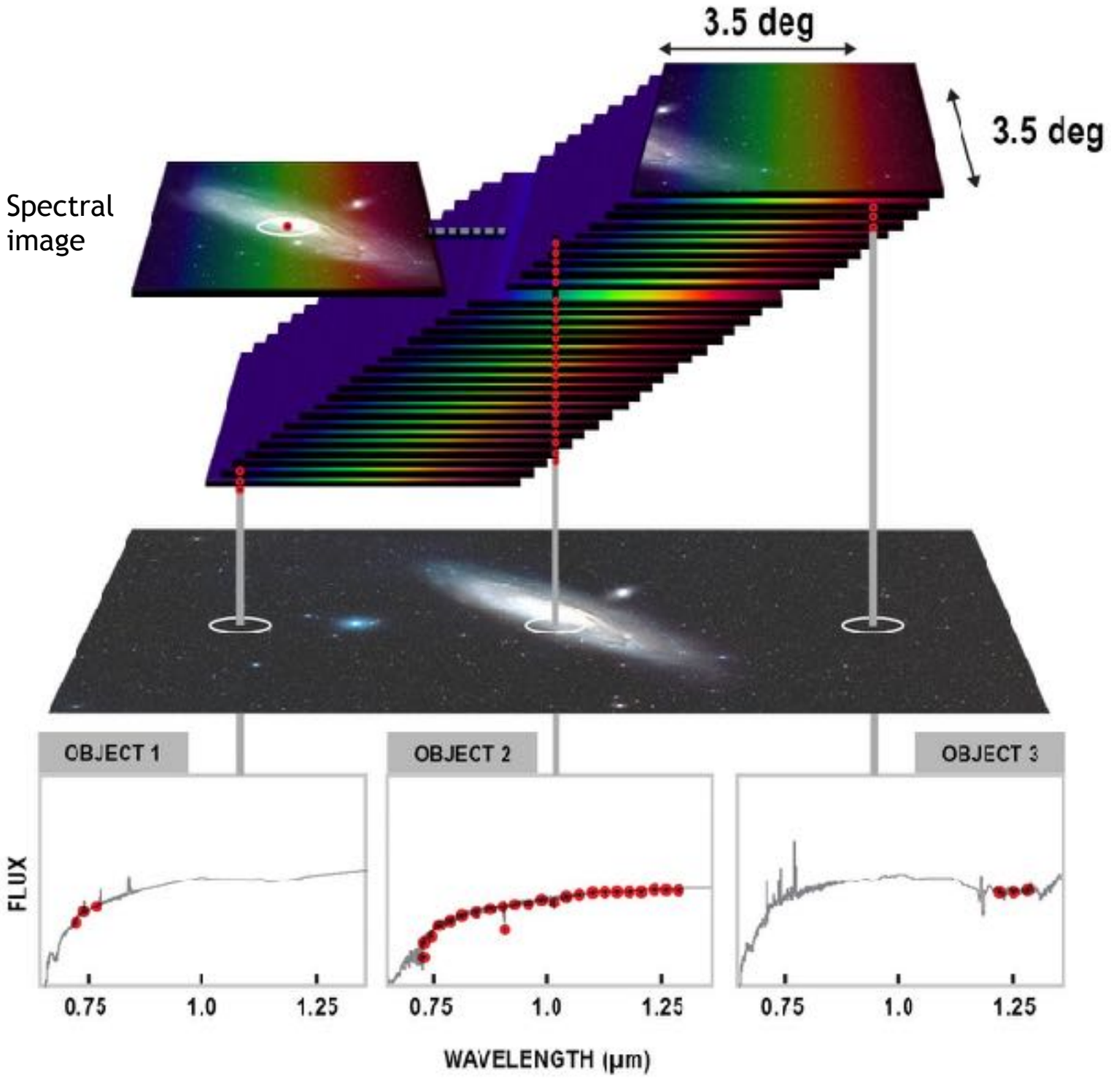


Linear Variable Filter



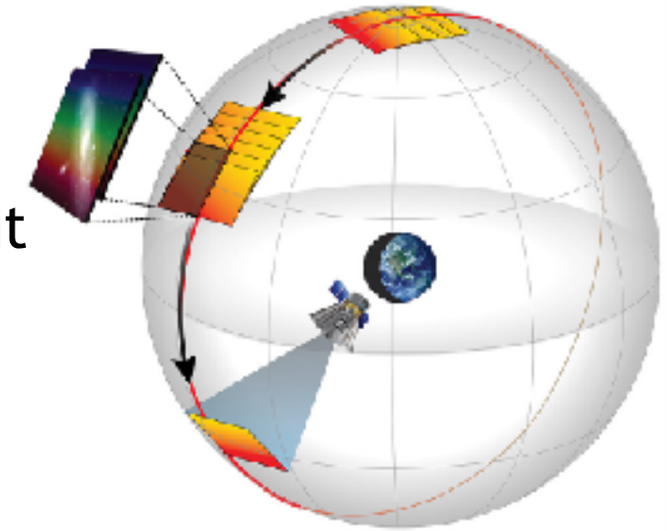
Spectra obtained by stepping source over the FOV in multiple images: **no moving parts**

Mapping the Sky with LVFs

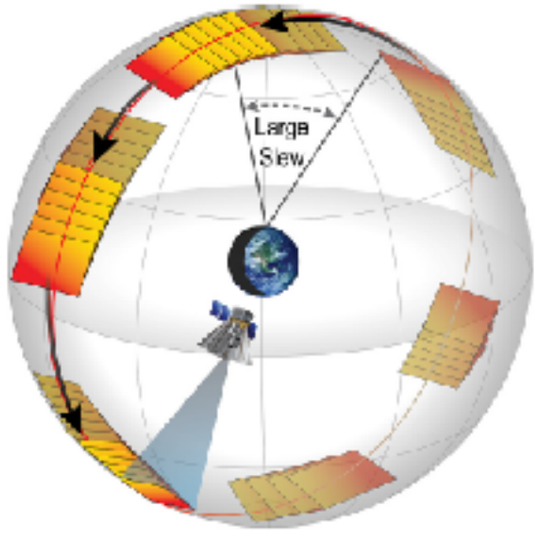


A complete spectrum is made from a series of images

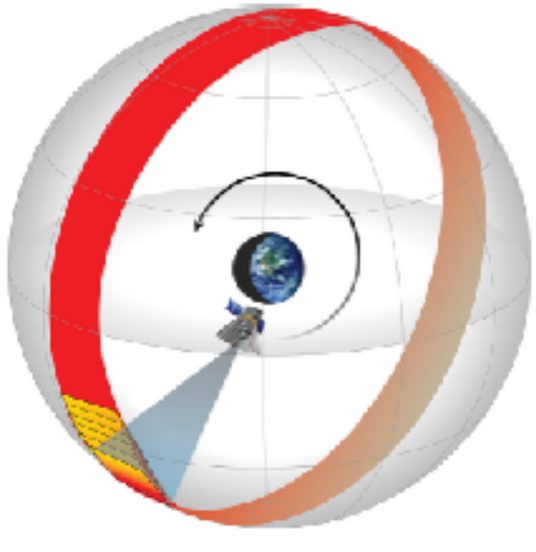
1 orbit



2 orbits



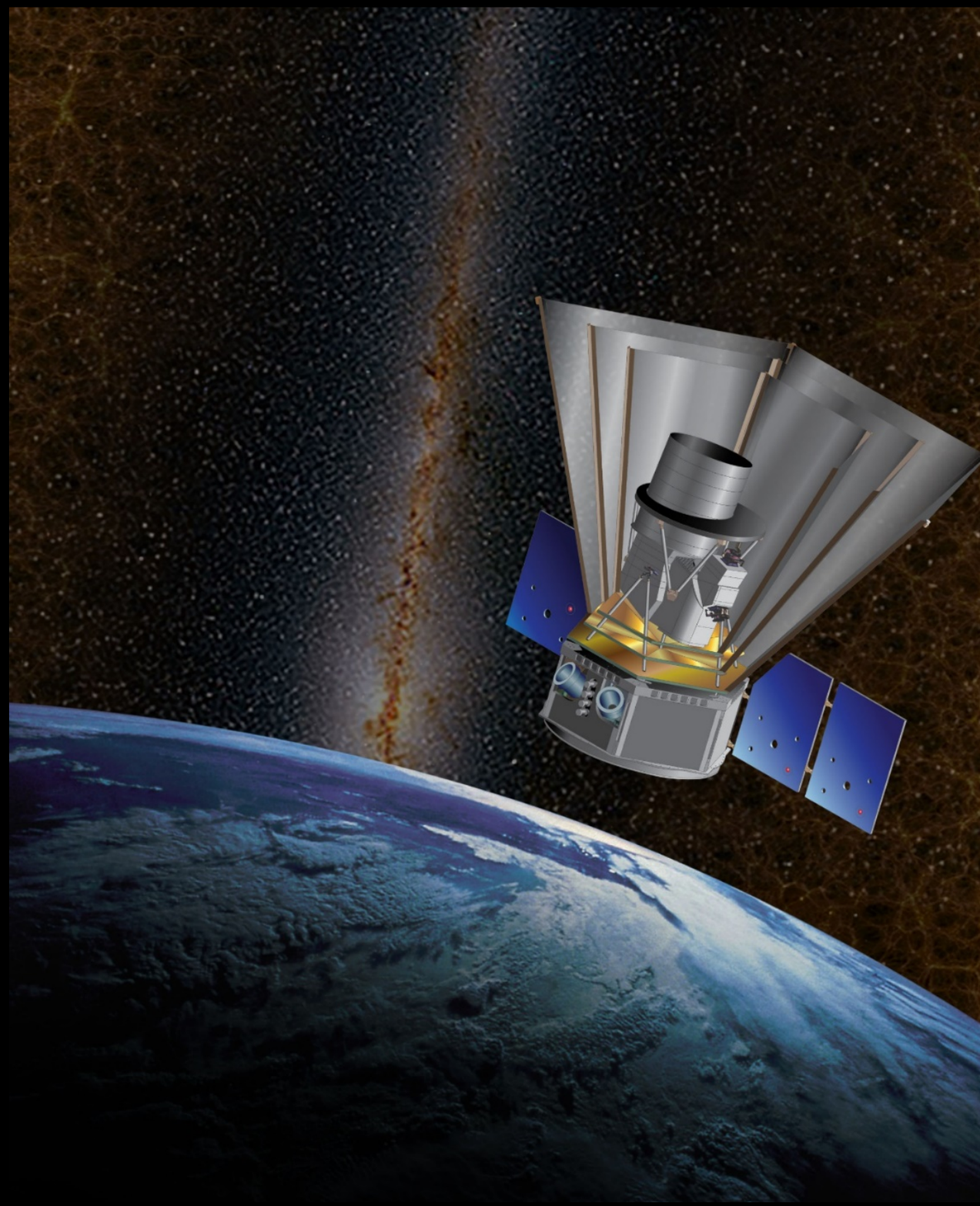
N orbits



SPHEREx maps the sky over multiple orbits with large and small slews

SPHEREX TEAM

Jamie Bock (PI)	Caltech/JPL	**Roland de Putter**	Caltech
Matt Ashby	CfA	**Tim Eifler**	JPL/U. Arizona
Peter Capak	Caltech/IPAC	**Rachel Akeson**	Caltech/IPAC
Asantha Cooray	UC Irvine	**Yan Gong**	UC Irvine
Brendan Crill	JPL/Caltech	**Lindsey Bleem**	Argonne
Olivier Doré (PS)	JPL/Caltech	**Daniel Masters**	JPL/Caltech
Chris Hirata	OSU	**Phil Mauskopf**	ASU
Woong-Seob Jeong	KASI	**Tzu-Ching Chang**	JPL/Caltech/ASIAA
Minjim Kim	KASI	**Hien Nguyen**	JPL
Phil Korngut (IS)	Caltech	**Karin Öberg**	CfA
Elisabeth Krause	JPL/U. Arizona	**Davy Kirkpatrick**	Caltech/IPAC
Dae-Hee Lee	KASI	**Harry Teplitz**	Caltech/IPAC
Gary Melnick	CfA	**Volker Tolls**	CfA
Roger Smith	Caltech	**Salman Habib**	Argonne
Yong-Seon Song	KASI	**Katrin Heitmann**	Argonne
Stephen Unwin	JPL	**Karin Sandstrom**	UCSD
Michael Werner	JPL	**Carey Lisse**	JHU
Michael Zemcov	RIT	**Rogier Windhorst**	ASU



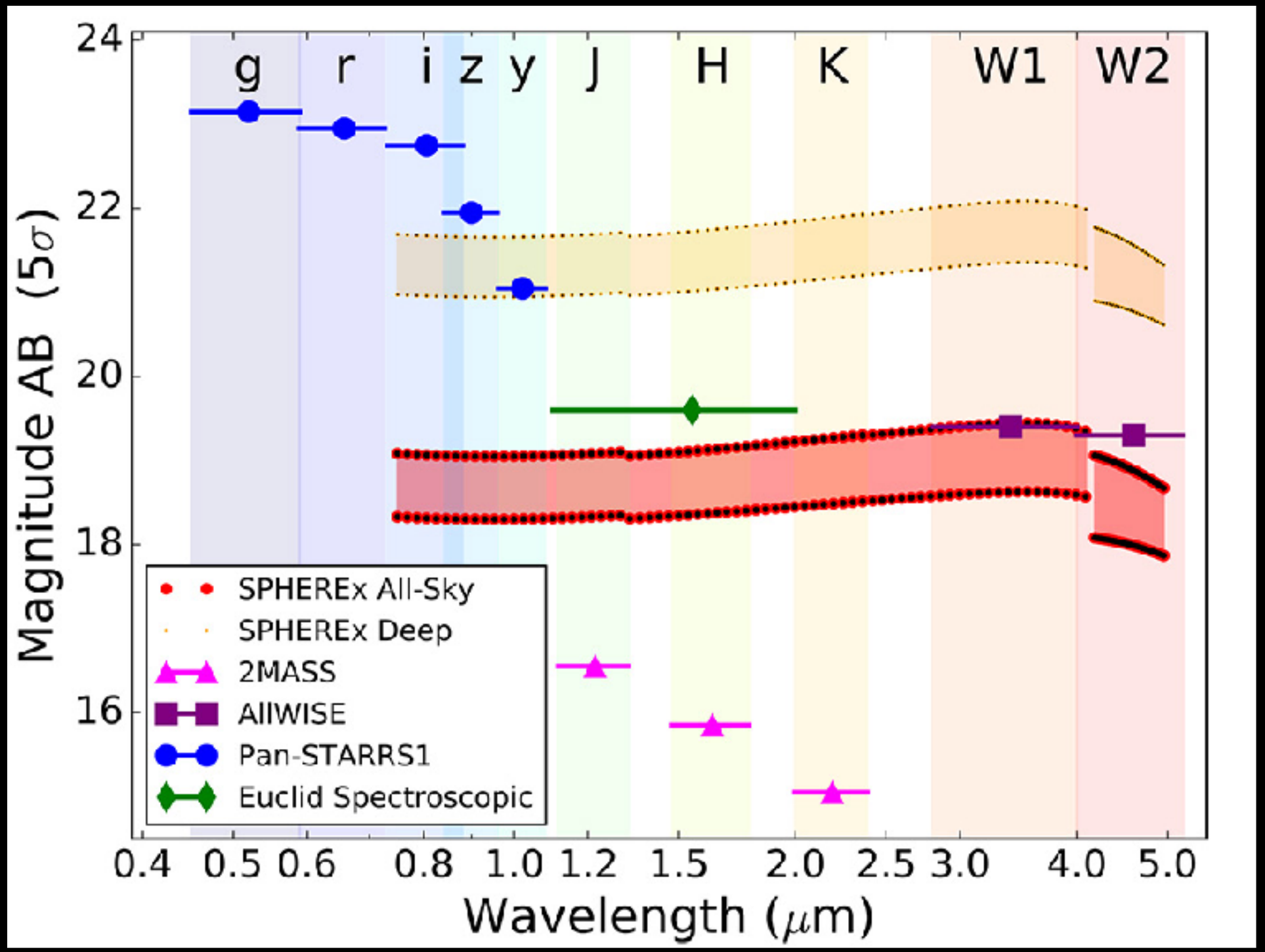
THREE MAJOR SCIENTIFIC THEMES

- How did the Universe begin?
  - ➡ Probing Inflation with the 3D clustering of galaxies.
    - Survey the z<1.5 Universe to fundamental limits to measure signatures of inflation (non-Gaussianity, primordial power spectrum shape) and dark energy.
    - Complement Euclid & WFIRST which survey smaller area at z>1.

- How did Galaxies begin?
  - ➡ Measure the extra-galactic background light (EBL) to probe the epoch of reionization (EOR) (⇐ Tzu-Ching's talk tomorrow).

- What are the Condition for Life Outside the Solar System?
  - ➡ Measure broad *ice* absorption features in stellar spectra to explain how interstellar ices bring water and organic molecules into proto-planetary systems.

SPHEREX ALL-SKY SURVEY DEPTH



Deep survey

Full-sky survey

SPHEREX PROVIDES A RICH ALL-SKY SPECTRAL ARCHIVE

Galaxies

Detected
> 1 billion

Med. Accuracy z's
> 100 million

High Accuracy z's
10 million

Clusters
25,000

Stars

Main Seq. Spectra
> 100 million

Dust-forming
10,000

Brown Dwarfs
> 400

Cataclysms
> 1,000

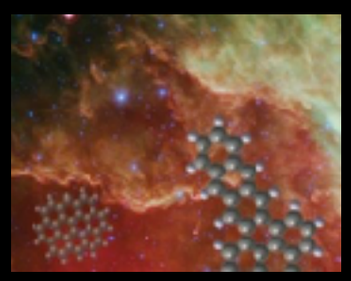
Other

Quasars
> 1 million

Quasars z >7
1 – 300?

Asteroid Spectra
10,000

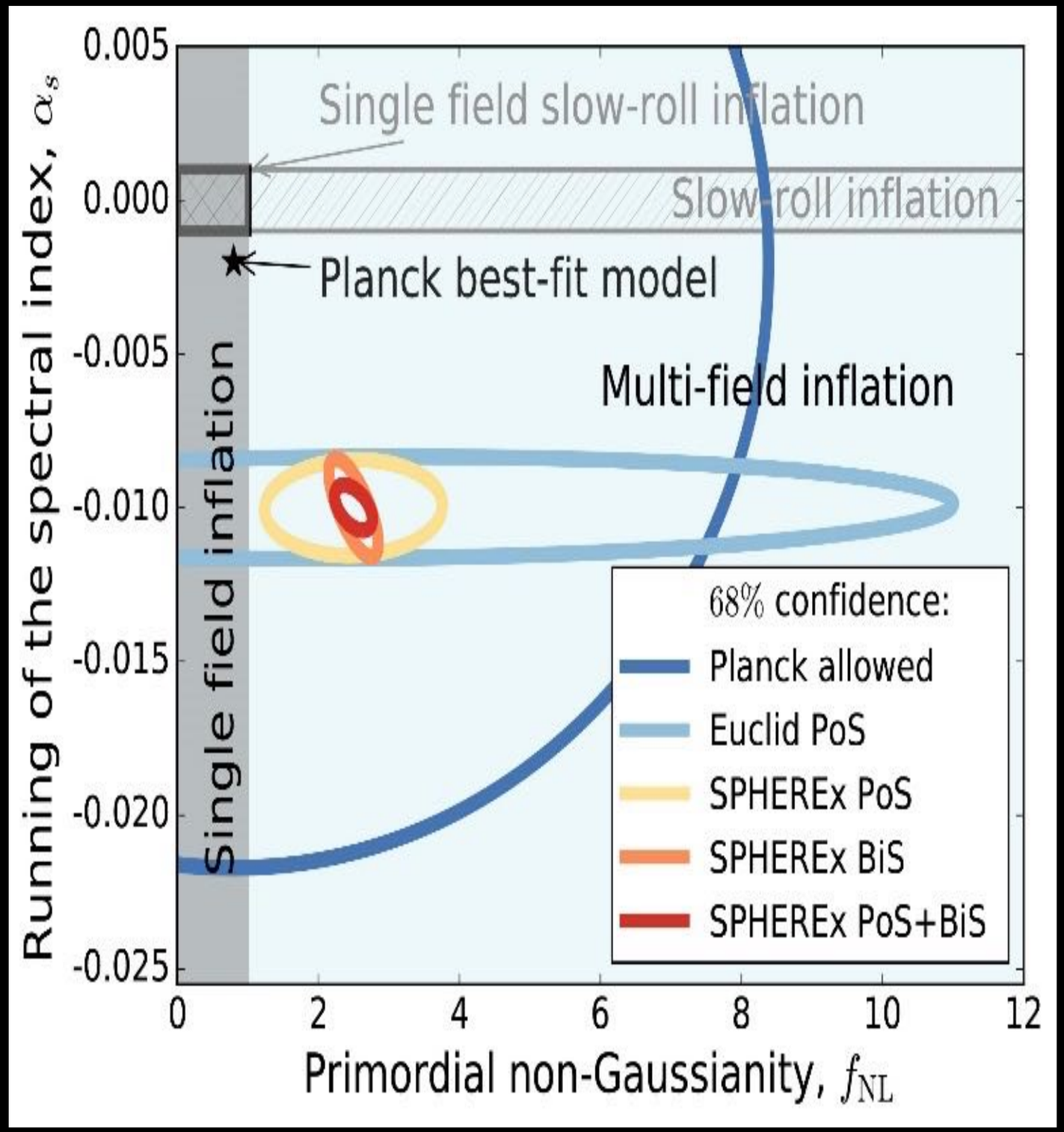
Galactic Line Maps
PAH, HI, H_2



All-Sky surveys demonstrate high scientific returns with a lasting data legacy used across astronomy

COBE
IRAS
GALEX
WMAP
Planck
WISE

SPHEREX AND INFLATION



- SPHEREx improves non-Gaussianity accuracy by >10
  - ➡ Improves $\Delta f_{NL} \sim 5$ accuracy today to $\Delta f_{NL} < 0.5$
- Discriminates between models
  - ➡ Single-field inflation $f_{NL} << 1$
  - ➡ Multi-field inflation $f_{NL} \gtrsim 1$
- SPHEREx improves non-Gaussianity accuracy by >10
  - ➡ SPHEREx produces a unique 3-D galaxy survey
  - ➡ Optimized for large scales to study inflation
  - ➡ Two independent tests of non-Gaussianity Improves

CONCLUDING ANSWERS

- What is primordial non-Gaussianity? Why measuring primordial primordial non-Gaussianity with large scale structures?
  - ➡ Primordial non-Gaussianity can discriminate multi-field and single field inflation and rule out single field inflation
  - ➡ LSS are needed as CMB is near cosmic variance limit

- How well do we need to measure primordial non-Gaussianity? What can a measurement with $\sigma(f_{NL})\sim1$ tell us about multi-field inflation?
  - ➡ $\sigma(f_{NL})\sim1$ is a natural theoretical target
  - ➡ Primordial non-Gaussianity can constrain the inflation Lagrangian

- What survey does it take to make measure $\sigma(f_{NL})\sim1$?
  - ➡ Large effective volume, moderate redshift accuracy, exquisite control of systematics on large scales

- A possible implementation, the SPHEREx mission

FIN